Intra-Operative Neurophysiologic Monitoring

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What is Intra-Operative Neurophysiologic Monitoring (IOM)?

- Intra-Operative Neurophysiologic Monitoring:
  - The Goal: Prevent Damage to the Nervous System During Surgery.
  - The Problem: The Patient is Anesthetized during Surgery and so it is not Possible to Perform the Standard Neurologic Examination.
  - The Solution: Monitor Electrical Studies that depend on the Integrity of Neural Structures.

IOM As An Extension of The Neurologic Examination

- Neurological Exam
  - Cognitive
  - Motor
  - Sensory
  - Reflexes
- IOM
  - Can Test Only When Awake
    - Indirect monitoring of Cortical Function
      - EEG
      - Cerebral Blood Flow
  - Multiple Modalities
    - MEP (motor evoked potentials)
    - CMAP(compound motor evoked potentials)
  - Sensory EP's
    - SSEP
    - BAER
    - Nerve Action Potential
  - H Reflexes

Specific Purposes of IOM

- Issue warning to the surgical team when there is significant evidence of impending injury to important neural structures.
  - Also provide SEVERITY of warning!!!!!
- Provide information to help guide the surgical resection of lesions, placement of electrodes, or placement of lesions.
  - Also provide level of CONFIDENCE information!!!!
- Training
  - If there are negative outcomes of surgical procedures, correlation of warning with surgical events helps surgeon understand which specific maneuvers place the patient at highest risk and modifies technique in the future to avoid them.

History of IOM

- 1920's-Electrical Stimulation for Localization (Foerster)
  - Awake Patients
- 1930-1950-EEG Recording from Cortex to Localize Epilepsy (Foerster, Jasper, Penfield)
  - Awake Patients
- 1977---First Report of IOM during spine surgery (Nash and Brown).
  - First Studies with Patients under General Anesthesia
- 1980's--Applications of Evoked Potentials to Brain, Brainstem, Extracranial EMG
- 1986—Application of Transcranial Doppler in the OR
- 1994—EMG Monitoring For Pedicle Screw Placement
- 2002---FDA Approval for Motor Evoked Potentials (MEP)

Modalities Monitored-I

- EEG (Electroencephalogram)
  - Spontaneous Electrical Activity in the Brain
    - Sensitive to injury to large areas of brain.
- Sensory Evoked Potentials
  - Responses to Stimulation
  - Visual Evoked Potentials
  - Auditory Evoked Potentials
  - Upper and Lower Extremity Evoked Potentials
    - Sensitive to injury on specific pathways

Modalities Monitored-II

- Motor Evoked Responses
  - Response to Stimulation of the Motor Areas of the Brain
- EMG
  - Spontaneous Electrical Activity
  - Increases Briefly with Nerve Injury
- Nerve Conduction Studies
  - Integrity of Peripheral Nerves

Modalities Monitored-III

- Transcranial Doppler
  - Measures Blood Velocity in Major Cerebral Vessels.
- Near Infrared Spectroscopy
  - Measurements of Cerebral Oxygenation

Properties of Monitoring Modalities-I

Property	SSEP	BAER	EEG	Cortical EEG	MEP	TCD	NIR
Sensitive to Cortical Injury	++ (Only Parietal)	-	+++	++++ (Local)	-	-	-
Sensitive to Subcortical Injury	++ (Only Thalamus)	-	+/-	+/-	++	-	-
Sensitive to Brainstem Injury	++	++	-	-	++	-	-
Sensitive to Ischemia	++	++	+++	++++	+++ (Esp Cord)	+++	+++
Sensitive to Seizures	-	-	+++	++++	-	-	-

Properties of Monitoring Modalities-II

Property	SSEP	BAER	EEG	Cortical EEG	MEP	TCD	NIR
Sensitive to Narcotics	-	-	++	++	+/-	-	-
Sensitive to Halogenated Anesthetics	++	-	+++	+++	+++	-	-
Sensitive to Propofol	+	-	+++	+++	+	-	-
Difficult to Setup	++	+	++++	+	+++	+	-
Difficult to Interpret	+	+	+++	++++	+	+	++
Rate of Technical Failure	+	++	+	++	++	++	+

Choice of Monitoring Modality Dependson Structure at Risk and Mechanism of Injury

- Structure at Risk
  - Peripheral Nerve
    - EMG
    - Nerve Conduction Study
    - SSEP
  - Spinal Cord
    - MEP
    - SSEP
  - Brainstem
    - BAER
    - SSEP
    - MEP
    - Cranial Nerve EMG
  - Brain
    - EEG, SSEP
    - TCD, NIRS

- Mechanism of Injury
  - Vascular
    - Hypotension
    - Vascular Occlusion
  - Mechanical
    - Compression
    - Stretch
  - Anatomic Misidentification
    - Is the Structure Seen By the Surgeon What it Appears to Be?

A Very Simple Example
“Getting the Data”

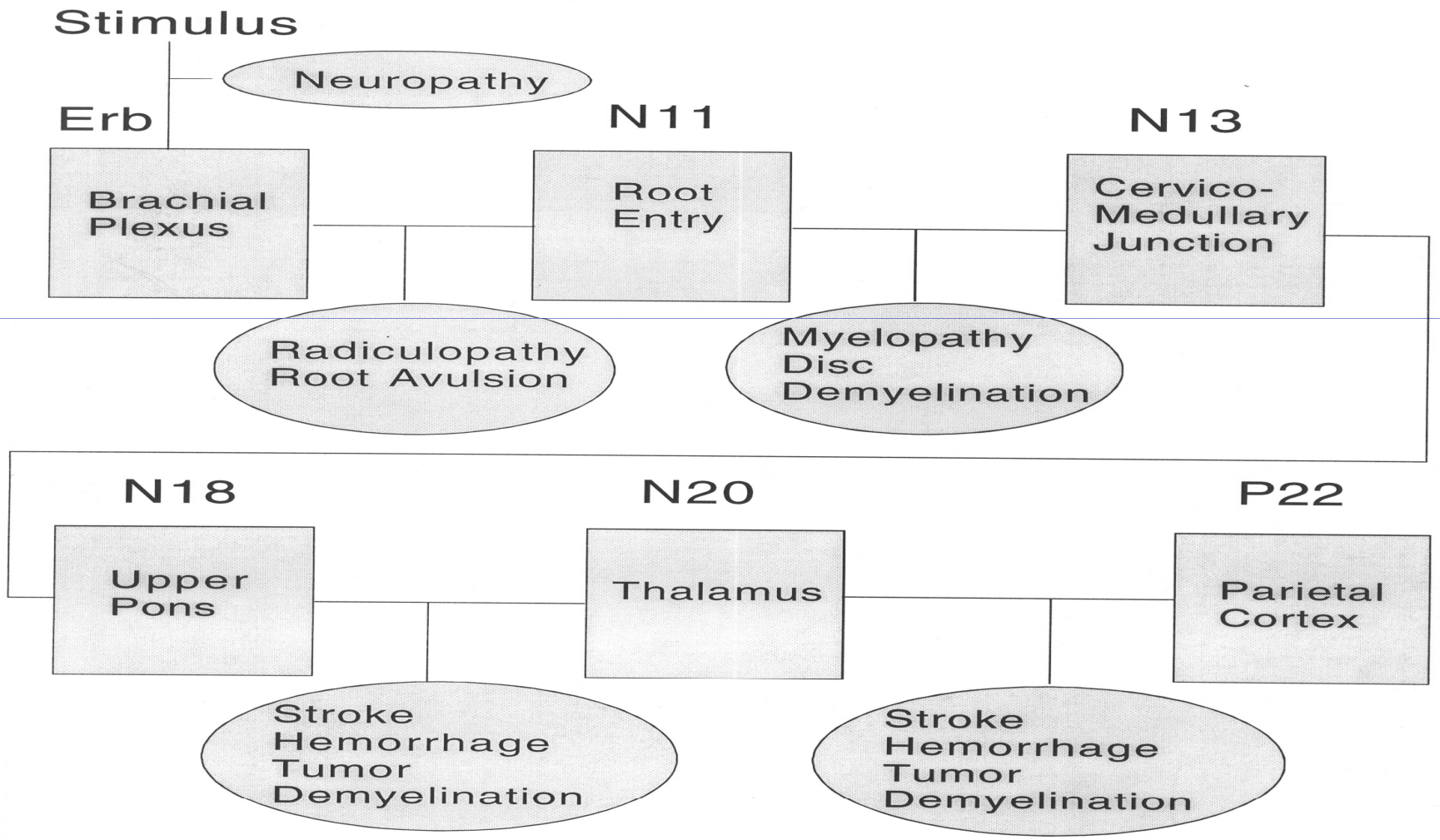
Monitoring Upper Extremity SSEP
During Surgery to Repair a Basilar Aneurysm

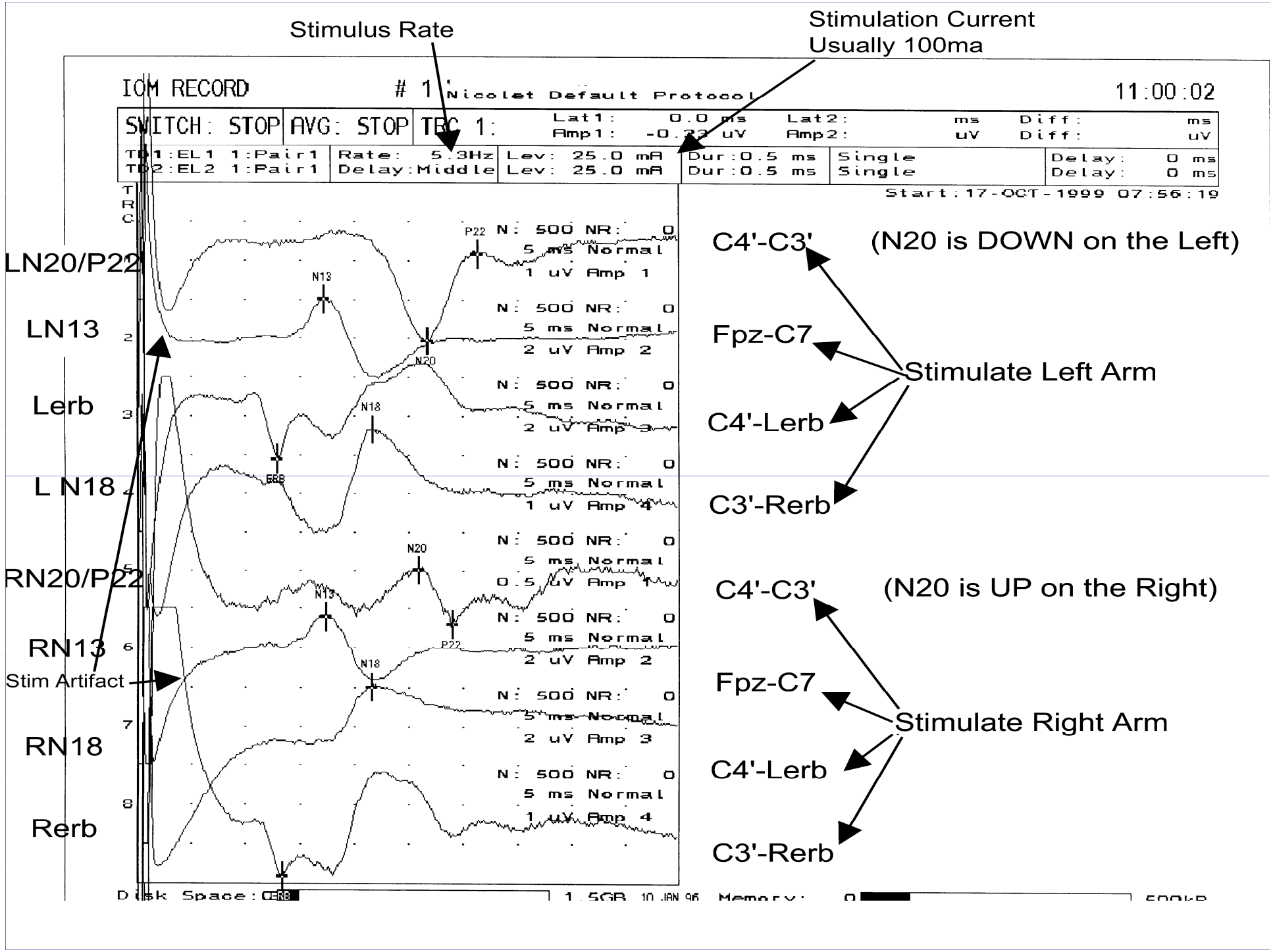
It’s NOT Easy!!!!!!!!!

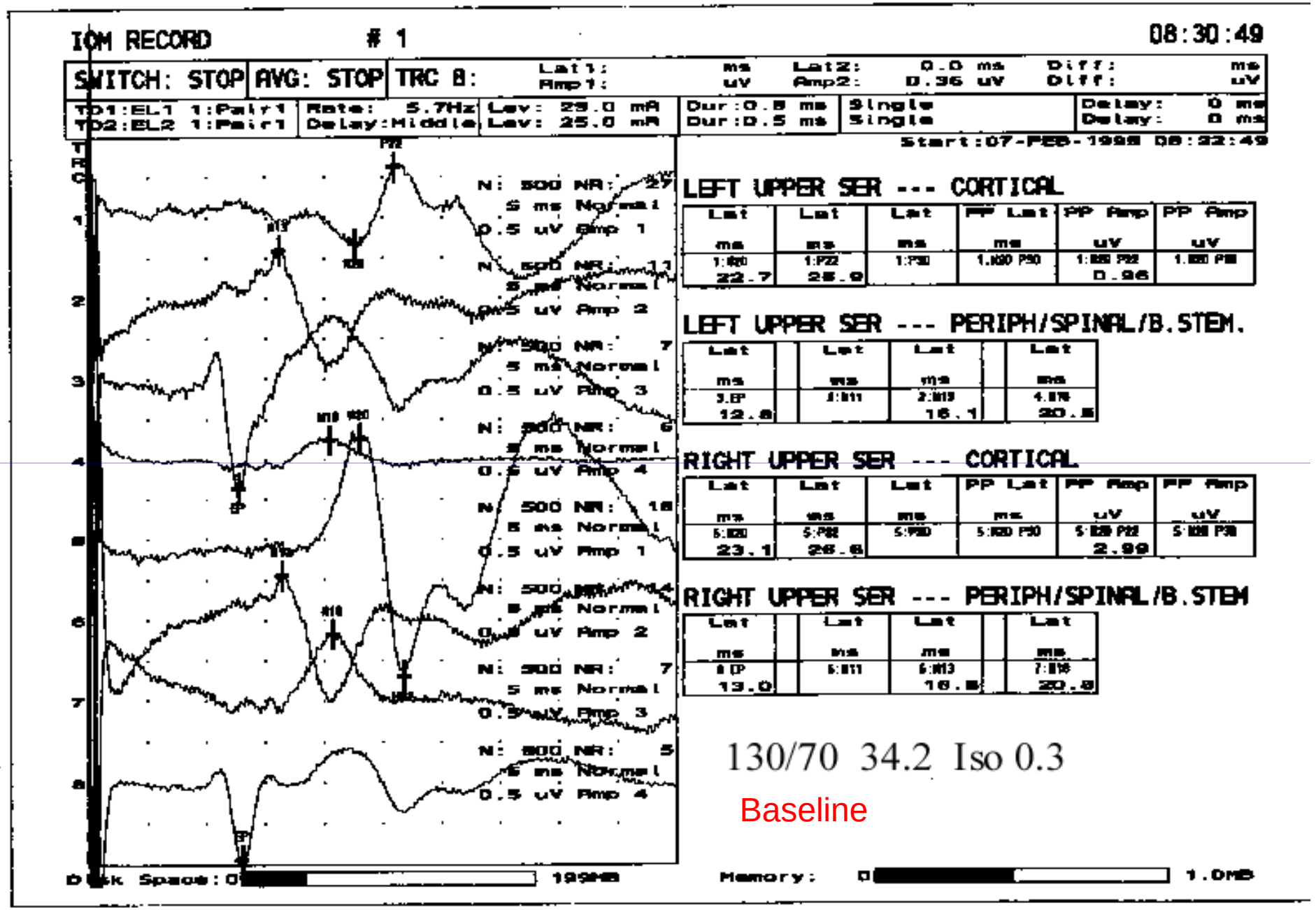
Upper Extremity SEP's

- Erb's Point---Brachial Plexus
- N11----------Root Entry Zone
- N13----------Cervico-Medullary Junction
- N18----------Ponto-Mesencephalic Junction
- N20----------Thalamus
- P22----------Cortex

Schematic Correlation of SEP Structures and Neuroanatomy

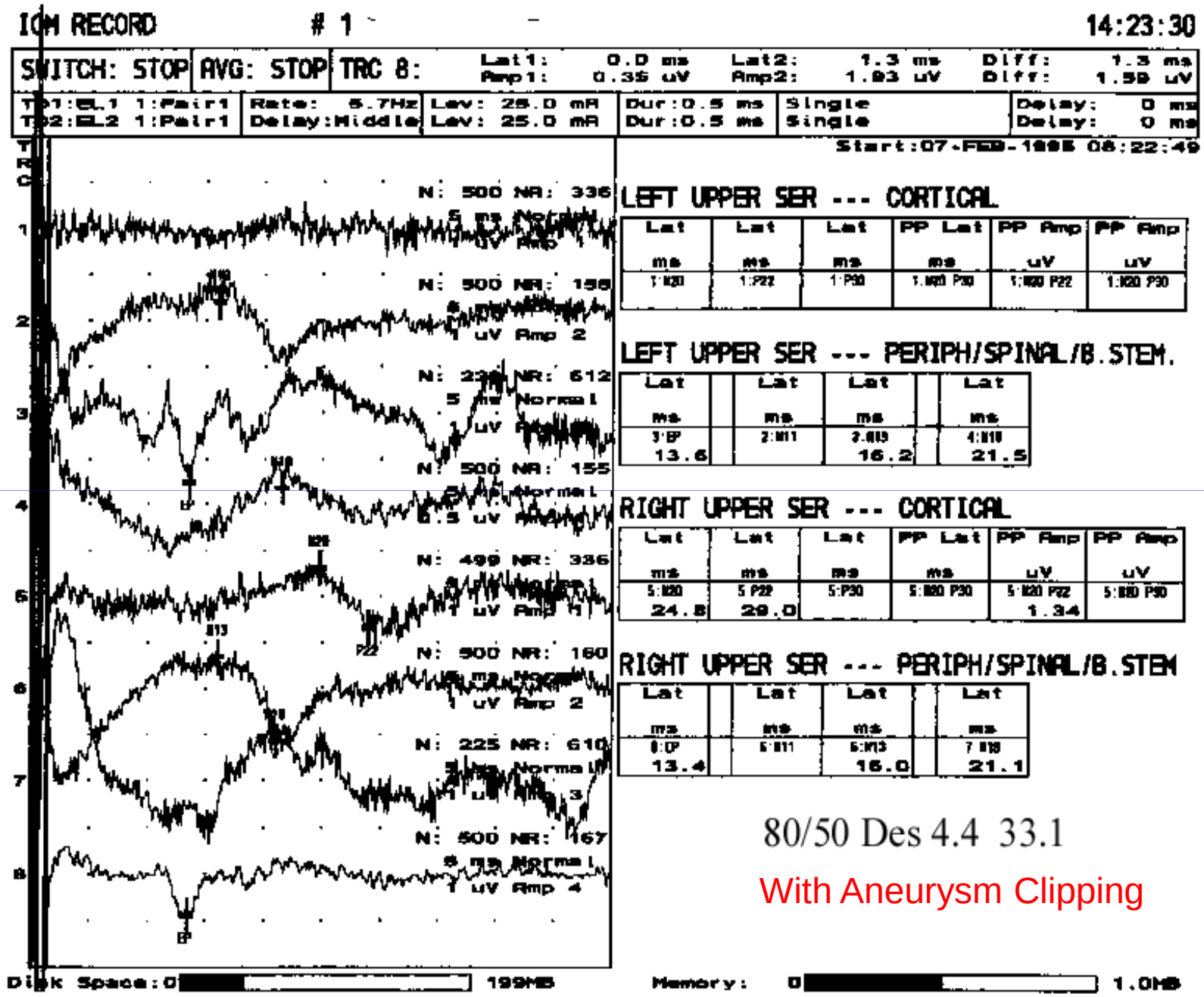



Stimulus Rate
Stimulation Current
Usually 100ma
IOM RECORD
1
Nicolet Default Protocol
11:00:02
SWITCH: STOP
AVG: STOP
TRC 1:
Lat1: 0.0 ms
Amp1: -0.23 uV
Lat2: ms
Amp2: uV
Diff: ms
Diff: uV
TD1:EL1 1:Pair1
TD2:EL2 1:Pair1
Rate: 5.3Hz
Delay:Middle
Lev: 25.0 mA
Lev: 25.0 mA
Dur:0.5 ms
Dur:0.5 ms
Single
Single
Delay: 0 ms
Delay: 0 ms
Start:17-OCT-1999 07:56:19
LN20/P22
LN13
Lerb
L N18
RN20/P22
RN13
Stim Artifact
RN18
Rerb
C4'-C3'
(N20 is DOWN on the Left)
Fpz-C7
Stimulate Left Arm
C4'-Lerb
C3'-Rerb
C4'-C3'
(N20 is UP on the Right)
Fpz-C7
Stimulate Right Arm
C4'-Lerb
C3'-Rerb



130/70 34.2 Iso 0.3

Baseline



80/50 Des 4.4 33.1

With Aneurysm Clipping

Using the Data

Interpreting Changes In IOM-I

- The Key
  - Although IOM results reveal some information about the nervous system, the relationship between changes in monitored variables and clinical outcome is NOT obvious and NOT fully explored.
- The Problem
  - Changes in many physiologic variables such as temperature, blood pressure, anesthesia, position, changes in recording or stimulating electrodes ALL affect IOM.
  - To date it has not been possible to automatically control for the effects of all of these variables.
  - No reliable large scale studies to define specificity and sensitivity of warnings provided by IOM.

Interpreting Changes In IOM-II

- The Solution
  - Consensus of expert opinion regarding warning criteria.
    - 50% decrease in amplitude
    - 10% increase in latency
  - Warnings should be issued based on detailed knowledge of the surgical events.
    - A change happening when the surgeon is working on the skin is less significant than when the surgeon is working directly on the spinal cord.
  - Warnings are more significant when there is evidence from multiple different tests that there is a potential problem.

Interpreting Changes In IOM-III

- The key to providing appropriate interpretations of significant warnings is:
  - Training
  - Experience
  - Education
  - Cooperation between Surgery, Anesthesia, Monitoring Teams
- Technicians are to provide waveform descriptions NOT interpretations
- Neurophysiologist or Neurosurgeon is to provide interpretations.

Differences Between IOM and Diagnostic Procedures-I

- Although IOM uses standard diagnostic procedures, the practice of IOM is VERY DIFFERENT than that of diagnostic neurophysiology:
  - Results
    - IOM---must be immediate (<3 minutes)
    - Extra-Operative Diagnostics—24 hours
  - Interpretation
    - IOM—Criteria are qualitative only based on consensus of experts not formal studies.
    - Extra-Operative Diagnostic----Formal criteria exist for interpretation with known sensitivity and specificity.

Differences Between IOM and Diagnostic Procedures-II

- Other differences between IOM and Extra-Operative Diagnostics
  - Performance
    - IOM---Testing is performed continuously and each test is compared to results from prior test and baseline.
    - Extra-Operative Diagnostics—Test performed once.
  - Multiple Tests
    - IOM—Performed simultaneously in order to confirm diagnosis.
    - Extra-Operative Diagnostic----Performed serially and can be interpreted separately.

Differences Between IOM and Diagnostic Procedures-III

- Other differences between IOM and Extra-Operative Diagnostics
  - Supervision
    - IOM---Requires personal supervision either by physical presence in the OR or by real time remote monitoring.
    - Extra-Operative Diagnostics—General or direct supervision is appropriate in most cases.

Summary

- IOM is an important technique for providing improved outcomes after complex surgical procedures.
- Although IOM uses various diagnostic modalities, it is very different requiring different staffing and interpretation.
- It is important to perform outcome studies
  - determine how often IOM is used.
  - determine which cases need monitoring
  - determine optimal criteria for interpreting study results.